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STEREOFUOROSCOPIC SYSTEM Final Report
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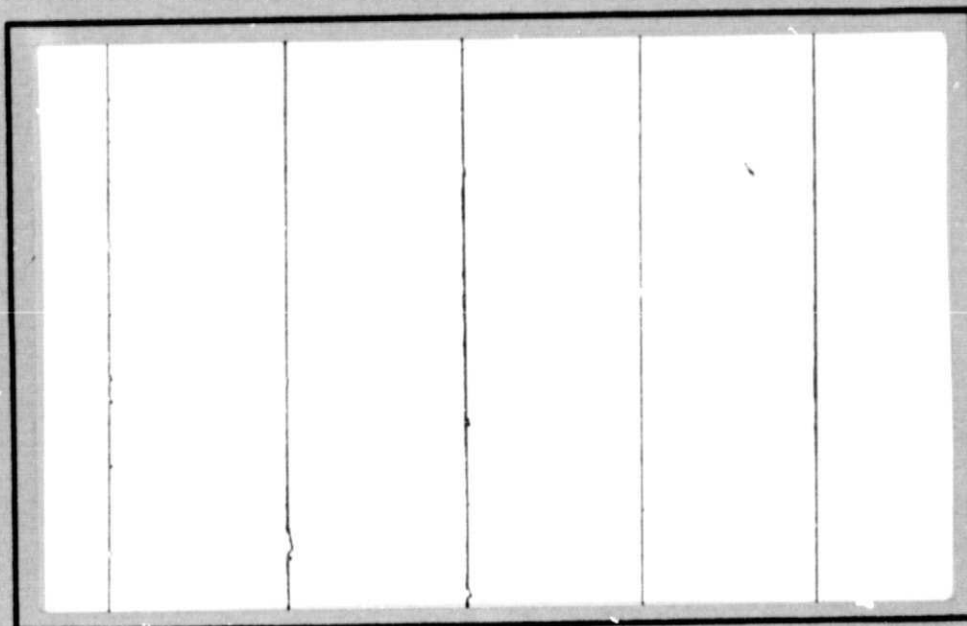
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**COLLEGE
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ENGINEERING**



**VIRGINIA
POLYTECHNIC
INSTITUTE
AND
STATE
UNIVERSITY**

**BLACKSBURG,
VIRGINIA**

IMPLEMENTATION OF A STEREOFLUOROSCOPIC SYSTEM

FINAL REPORT

29 October, 1976

NAS 9-14862

Dr. D. B. Rivers
VPI&SU
Blacksburg, Virginia

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INTRODUCTION

One of the major goals of the National Aeronautics and Space Administration is to be responsive to requests for application of aerospace technology to the public health sector. Johnson Space Center has been the leader in aerospace medical and communications development, two of the more obvious results of technology transfer being Telecare and STARPAHC. A newly developed technique of 3-D video imaging, developed by NASA for use on future manned missions for observation and control of remote manipulators has come to the attention of this investigator as having possible applications in the area of diagnostic fluoroscopic imaging.

Until the mid-1930's, many x-ray studies were performed with two x-ray tubes or poses and displayed in 3-D. Then, as information about the accumulated dose effects of x-rays became known, the stereo application fell into disuse until today the pendulum has moved completely away from this method and towards what today are 2-D x-ray fluoroscopic procedures. However, it should be noted that the discussions with leading radiologists across the country have led to the realization that there are many clinical applications of a stereo fluoroscopic system if such could be developed. Among these applications are cardiac catheterization, hip pinning, angiography, and ulcer detection, not to mention possible uses in the industrial quality control field. Testimonials to the possible uses of this system by clinicians in various fields are reproduced in the Appendix.

The reason that such a system does not exist in widespread use is twofold: lack of a method of reducing the dose to the patient (and the physician as well since some studies have demonstrated that this might be the real limiting factor) and lack of an adequate viewing system. However, both of these stumbling blocks can now be overcome through the application of present state-of-the-art technology. There has been much work done in the past three years in dose reduction of fluoroscopic systems by using grid pulsed x-ray sources which can greatly lower the dose rate by instantaneously shutting off the source between the taking of each video frame (30/second). In addition, the development of the high speed video disc for instant video replay of sports action has created a system which can store an image and then display and re-display it on the CRT with loss of only a few milliseconds. Consequently, fewer frames per second need be taken except in exceptionally rapidly changing events and a lowering of the total dose is achieved.

Both of the above systems have already been combined into 2-D fluoroscopic systems which require substantially lower outputs of radiation to function (1).

Figure 1 shows the NASA developed stereotelevision system visualization problem (NASA Tech Brief B74-10223). A fluoroscopic image is actually a 2-D view of a system which is 3-D in space, thus causing one of the leading difficulties in analyzing fluoroscopic images. However, this is exactly the type of input most readily handled by the NASA system. Although other 3-D viewing systems have been examined in various research centers as possible alternative solutions to stereofluoroscopy imaging, including red-green color TV images and beam splitters using polarized light, all of the other systems greatly restrict the vision of the user, the resolution of the

picture, the number of people capable of viewing the output, and the mobility of the user. The NASA device overcomes all these problems.

Consequently, it is proposed that serious consideration be given the application of the NASA-developed stereotelevision to the development of a stereofluoroscopic viewing system for clinical usage, a system which is within the present capability of radiological and space technology.

Brief History of Stereoscopy

Attempts to obtain stereo images from a fluoroscopic screen are as old as the clinical use of the screen itself (2). By the early 1960's, the advent of the image intensifier (II) screen led to renewed interest in this project due to the gross reduction in patient dose that the II allowed. Several experimental systems were proposed by Lindblom (3), Webster (4), and especially Stauffer (5,6).

Some of these systems were actually built and used in limited clinical applications. Later work by Kok (7,8) and most recently by Du mmeling (9) and Künnen (10) show that currently there is still research and clinical interest in such a device.

However, in all these systems there remains the critical problem of developing an adequate display capability, one which would lend itself to clinical use, especially in an operating room. Such a device should provide a stereofluoroscopic view to any number of viewers (including multiple displays), allow mobility of each of these viewers, be free from the necessity of correction for the random visual parameters of each viewer such as intraocular distance, and also allow the viewer to look away from the output device and enjoy normal sight without having to adjust or remove any necessary viewing glasses or other decoding device. It is only the NASA developed PLZT goggle system which lends itself to the solution of all of the above mentioned problems.

Approach

The development of this 3-D fluoroscopy system should be accomplished in two phases. In the first phase a breadboard laboratory system should be developed as shown in Figure 2, with the exception of the video taping and video disc storage components. This Phase I system should be built only to demonstrate the utility of visual output for evaluation by radiologists, engineers and other users, and, as such, would not be expected to produce radiation exposures which would meet current federal requirements for patient doses. It is suggested that initial image testing would involve only television type test patterns to discern output visual parameters. This would be followed by testing the system with inanimate radiologic phantoms to determine the quality of the x-ray image. Subsequent tests using mechanically animated animal cadavers would more fully demonstrate the utility of such a system. It is estimated that a one year period would allow adequate development of such a system.

Phase II would call for the modification of the Phase I system with grid-pulsed x-ray sources (if not implemented in Phase I) and the addition of an instantaneous video frame-by-frame replay device such as a video disc or a tape loop. This would allow the system to be modified so that patient exposure to radiation doses would be at or below the current government requirements, depending upon the pulse rate of the two x-ray sources. The entire device would then be ready for preliminary testing using first inanimate phantoms, then mechanically animated animal cadavers and, finally, clinical evaluation.

System Description

Stereo Television

Three-D images are built up in a normal individual's mind as a natural consequence of having each eye send a complete image of what it sees to the brain. Since there is some parallax distortion due to the offset anatomical placement of the eyes, these two views are slightly different. Once received by the brain, a single image impression is generated with depth.

NASA's 3-D TV system artificially presents the eyes with separate left and right images from a single video monitor, as shown in Figure 1. Two synchronized television cameras are both focused on the same scene from two slightly different angles, usually with a 6° difference. Each camera transmits 30 separate pictures, or frames, per second. Each frame is composed of approximately 500 lines and is transmitted by first relaying the odd numbered lines (called field one), then the even lines (field two). Consequently, each camera transmits 30 images as 60 fields. The mixer combines the outputs of both cameras by throwing out the even fields from the left camera and the odd fields from the right. Therefore, the signal from the mixer to the TV monitor is composed of the odd lines from the left camera alternating with the even lines from the right. This would be perceived as a double image on the monitor which is decoded into separate images for each eye by using the decoding goggles, actually the heart of the NASA stereo-video system. Each lens of the goggles is made of lead lanthanum zirconate titanate (PLZT) ceramic, which functions as a light valve. By applying or removing a voltage across

the PLZT wafers, each lens alternately passes, then blocks the impinging light in a duty cycle which is identical to that of the two cameras. Therefore, the left eye only receives light when the image from the left camera is presented, the right eye sees only the right camera's image and a stereo picture is constructed.

Stereo Fluoroscope

As can be seen in Figure 2, the fluoroscopic application of NASA's 3-D video system differs from the original only in terms of the input to the video signal mixer; the viewing system remains unchanged. Two-X-ray tubes are alternately pulsed to provide bursts of x-ray photons which pass through the patient's body and create alternate parallax images at the output of the image intensifier (II), a dose reduction device. These alternating images are synchronized to the single TV camera's scanning system so that, as before, 30 frames per second are generated. Each frame consists of a view of the II output caused by bursts from the left x-ray tube for field one and the right for field two. Note that to produce a frame rate of 30Hz, each x-ray tube must be pulsed at 30Hz. The above system creates a higher dose rate since each frame must be formulated from two x-ray bursts through the patient, double the conventional rate. However, by inserting a video disc recorder into the system, this increased dosage can be considerably reduced, in fact, reduced below that of conventional fluoroscopy. This can be performed by taking advantage of the instantaneous storage and retrieval capability of the video disc. The signal from the mixer can be sent into video disc storage instead of the monitor. Then the stored frames can be transmitted to the video monitor on a repeating basis, thereby using the II output only to update the storage disc,

not for direct video display. In this manner the x-ray tubes need not be activated to obtain a continuous fluoroscopic image on the monitor. The tubes have to have paired pulses at the frame update rate only. Since many clinical fluoroscopic procedures are views of static systems or systems which are dynamic but do not require an update rate of 30 frames per second, using the video disc storage to feed the monitor would significantly reduce the patient's dose over that of continuous fluoroscopy without sacrificing the real time aspect of the viewing system. Of course, a video tape recorder could be attached to the system to provide a permanent record of the clinical test procedure in either stereo or monoptic form. The dose reduction system described above has been successfully performed experimentally using a conventional fluoroscopy setup and is readily adaptable to stereo viewing (1).

Equipment

The Phase I experimental laboratory setup depicted in Figure 2 would closely resemble a modified portable "C-arm" fluoroscopic unit. However, in all probability such a unit would not be available for the amount of off-line time that would be required for modification, testing and evaluation. Experience has shown that such units are almost continuously in use, or on call, in clinical situations. Consequently, either a new unit would have to be purchased at great expense, especially considering the reworking that would be required, or some other more cost efficient approach be found. An alternative method is suggested.

It has been determined that the turnover time for clinical fluoroscopic units is such that discrete components are almost continuously available from large fluoroscopic centers, such as medical centers. These components, although used, have been designed to meet exacting technical requirements and functions, many of which would not be directly applicable to this Phase I system. Consequently, although these components are no longer functional in the complete clinical sense, they would in many cases be more than adequate for the type of system described here. It is recommended that the two x-ray tubes, the image intensifier with power supply, and the TV chain, consisting of coupling lens, Plumicon tube video camera and monitor, be procured in this manner.

The PLZT goggle system would be furnished by NASA, due to their experimental nature, and a high voltage D.C. generator, needed to power the x-ray sources with 150 KV and 300 to 500 mA output, could probably

be located through surplus. The cost of all equipment procured in this manner would be in the order of \$15,000 and, conceivably less, depending on the specific components selected.

Facilities

The Phase I system could be developed in any laboratory with adequate radiation shielding. Ready access to technical expertise in high voltage technology, video imaging, and radiation physics would be most beneficial.

The Phase II system would be most effectively developed at, or in conjunction with the medical center where final clinical testing would take place. Typically this center would have an experimental or unused standard fluoroscopic room available for such purposes.

Cost Estimate

The following estimates are based on the premise of having all work performed in the Radiological Imaging Laboratory of the Virginia Polytechnic Institute and State University.

Phase I (Fiscal Year 1977)

Equipment	15 K
-----------	------

Direct Costs

lead engineer (Ph.D.)	
1/2 man year	7 K

assistant (B.S.)	
1/2 man year	4 K

Indirect Costs (@63%)	18 K
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Miscellaneous Costs	<u>1 K</u>
	35 K

Phase II (Fiscal Year 1978)

Equipment	12 K
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Direct Costs

lead engineer (Ph.D.)	
1/2 man year	8 K

assistant (B.S.)	
1/2 man year	5 K

Indirect Costs (@63%)	8 K
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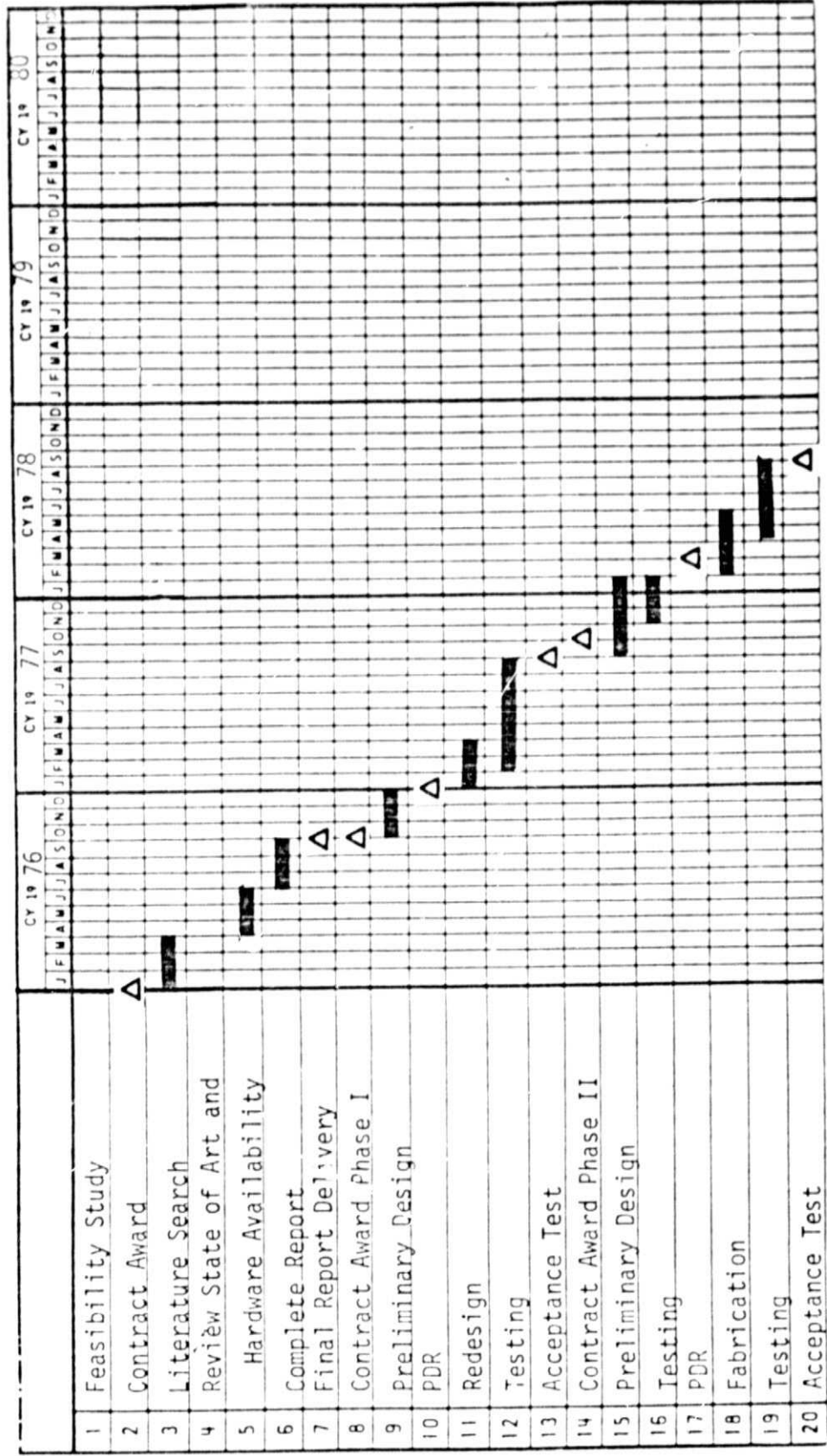
Miscellaneous Costs	<u>2 K</u>
	35 K

Total	<u>70 K</u>
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MILESTONE SCHEDULE



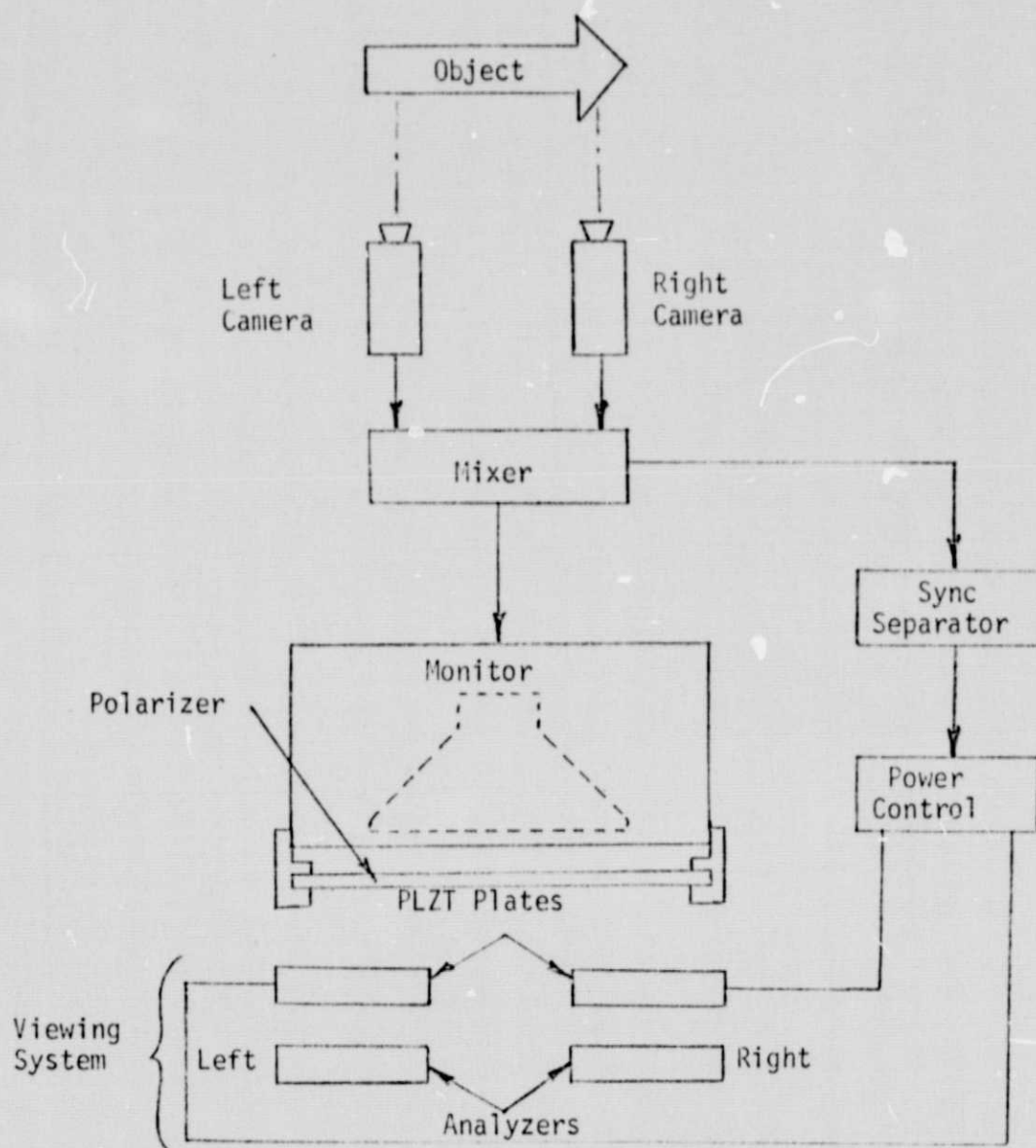


Figure 1. Field-Sequential Stereo Television System:
Twin-Camera System

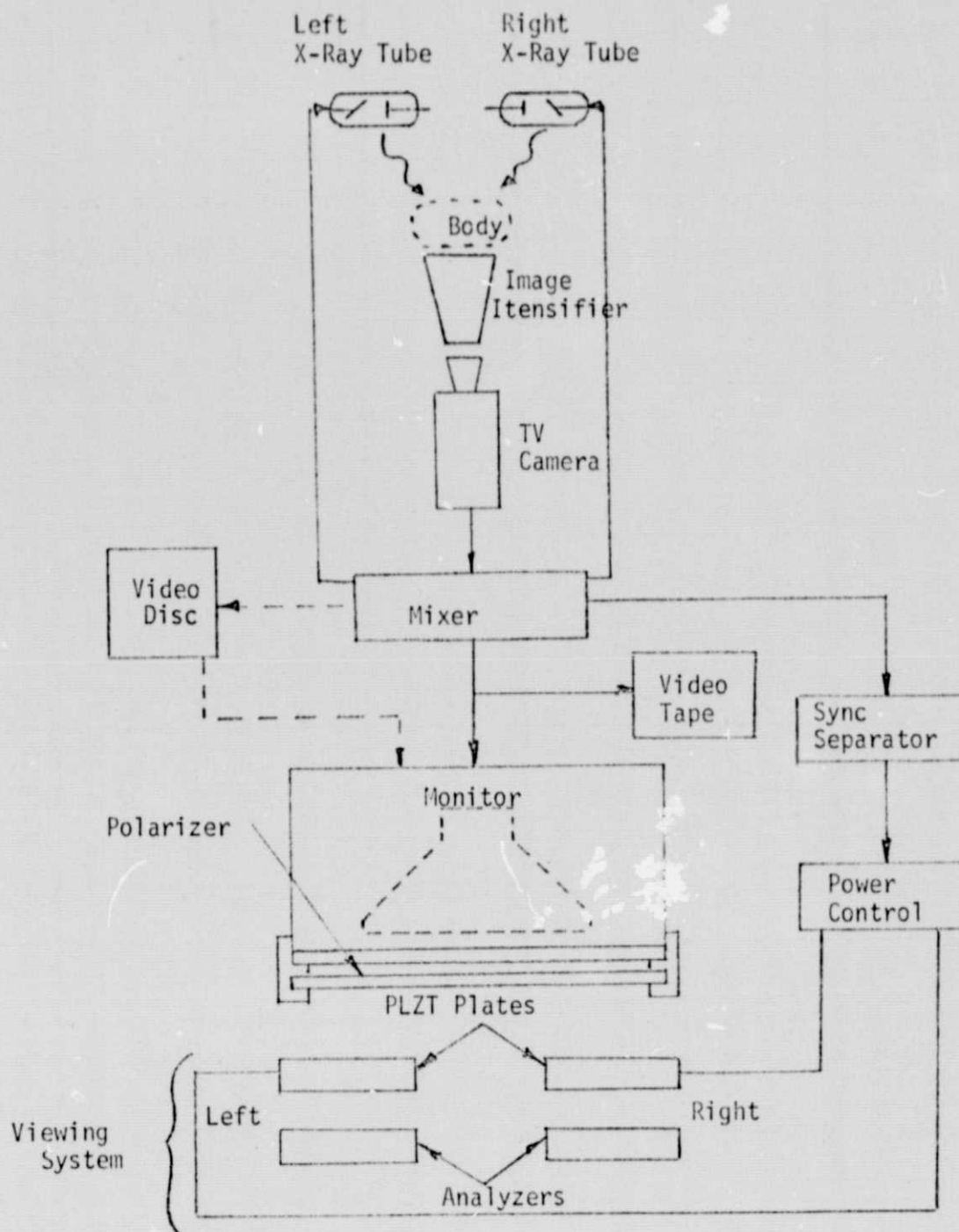


Figure 2. Stereofluoroscopy System

APPENDIX

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*Journal
of the
American Podiatry Association*

E. DALTON McGLAMRY, D.P.M.
Editor
1649 Brockett Road
Tucker, Georgia 30084

September 1, 1976

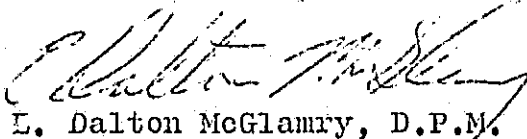
Mr. Dale B. Rivers
Assistant Professor
Department of Mechanical Engineering
Virginia Polytechnic Institute
Blacksburg, Virginia 24061

Dear Mr. Rivers:

I will be most interested in your work on three dimensional fluoroscopy. I feel that this has potentially great application in podiatry for examining biomechanical function especially in the patient with arthritis and other chronic diseases effecting the foot and ankle.

Please keep us informed as to the progress of this most interesting project.

Sincerely yours,



E. Dalton McGlamry, D.P.M.

dp

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DEPARTMENT OF MEDICINE

September 2, 1976

Dale B. Rivers
Assistant Professor
Department of
Mechanical Engineering
Virginia Polytechnic Institute
and State University
Blacksburg, Virginia 24061

Dear Dale:

It was a pleasure to see you in Atlanta this week and catch up on your recent activities. I am intrigued by the description of the NASA stereo-fluoroscopy system contained in your technical report. This system would appear to have considerable potential for clinical application in Cardiac Catheterization Laboratories. A significant contribution might be made in the area of arteriography: e.g. in coronary arteriography where three dimensional viewing of small vessels surrounding a spherical mass (the heart) is very important. Applications also suggest themselves in the area of ventriculography where an irregular, solid geometric structure must be analyzed during changes in shape and size. Video recording systems for instant replay are used in conjunction with the fluoroscopy and cine filming equipment in most catheterization laboratories and could probably be adapted to the videodisc component in order to reduce radiation dosage to the patient. Two problem areas would seem to be: (1) integration of stereo fluoroscopy with the cine system and videodisc/videotape system-including related problems of cost and size; (2) the method of stereo viewing for the physician and/or technicians - the "goggles" are not described and the method of "stereo viewing" a monitor TV screen could be a major problem.

Keep me posted on your work in this area.

Sincerely,



Donald O. Nutter, M.D.
Professor of Medicine (Cardiology)

DON:ch

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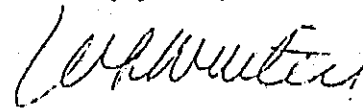
September 24, 1976

Dr. Dale Rivers
Associate Professor of Mechanical
Engineering, VPISU
Blacksburg, Va. 24061

Dear Doctor Rivers:

Mike Smith at Methodist Hospital here in Houston has given me your name and address and discussed briefly with me your interest in stereofluoroscopy. My purpose in writing is to re-enforce his belief that in cardiac catheterization work stereofluoroscopy would be extremely valuable. I was first intrigued with this concept as a young Cardiologist in Philadelphia at the Temple University Medical School where Dr. Herbert Stauffer of the Radiology Dept. and several members from General Electric worked for a number of years on stereoscopic fluoroscopy using colors, I believe green and red. I moved from Philadelphia and lost track of the development of their work but have always felt strongly that stereofluoroscopy would offer a great deal to the individual doing cardiac catheterization work. I am still actively involved in the catheterization laboratory at Methodist Hospital and wanted to add my endorsement for such investigation.

Sincerely yours,



William L. Winters, Jr., M.D.

WLW:rjh

GEORGETOWN UNIVERSITY HOSPITAL

3800 RESERVOIR ROAD, N.W.
WASHINGTON, D.C. 20007

DEPARTMENT OF RADIOLOGY

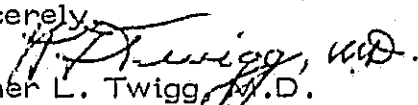
March 1, 1976

Mr. Dale Rivers
Dept. of Mechanical Engineering
Virginia Polytechnic Institute
and State University
Blacksburg, Virginia 24061

Dear Mr. Rivers:

Reference to our conversation, this morning, the concept of stereo fluoroscopy is an interesting one. Our present technology for three dimensional localization is fairly accurate. To be able to do so with a fluoroscope may have some medical applications, particularly in operative and special procedures where it is difficult to move the patient and you wish to localize a lesion, instrument, or catheter. It would be worth pursuing the clinical application of such an instrument providing, of course, the expected results would be beneficial to the patient, and the Federal Radiation Standards would be observed. I will be interested in hearing of further developments of this technology.

Sincerely,


Homer L. Twigg, M.D.
Professor and Chairman

HLT/r

October 6, 1976

Dale B. Rivers Ph.D
Virginia Polytechnic Institute
and State University
Blacksburg, VA 24061

Dear Dr. Rivers:

After our discussion at the Houston Office and a review of your paper given on Stereo-Fluoroscopy we contacted our German Factory to discuss the possibilities and Marketing chances for Stereo Fluoroscopy.

As a result, the decision was made that Siemens Corp., right now, is not able to assist or promote you in your efforts to find a way to achieve the Stereo Fluoroscopy views out of a X-Ray images, however, you should be aware that Siemens always tries to be a progressive company, therefore, we are still interested in the progress of your Stereo Fluoroscopy System.

As soon as a functional unit should be available, please let us know so a further relationship might be discussed.

If anymore questions come up, don't hesitate to contact me here in Iselin.

Sincerely yours,

SIEMENS CORP.
Medical System



Bernd Keusemann

cc, K. Price
J. Keller
M. Fink
L. Kleiner



Development Corporation
505 King Avenue
Columbus, Ohio 43201
Telephone (614) 424-6424
Telex 24-7451

February 25, 1976

Dr. Dale Rivers
Department of Mechanical Engineering
Virginia Polytechnic Institute
and State University
Blacksburg, VA 24061

Dear Dr. Rivers:

I wish to thank you for bringing me up to date on the status of the development of your 3-D Fluoroscope. As I understand it, NASA is seriously considering your proposal for continued development.

As I have said before, BDC has an interest in the concept--not only for medical uses, but possibly for other applications. As you know, we are a licensing organization with marketing capabilities worldwide.

If NASA funds the development, we would very much like to have the opportunity of evaluating the development at the completion of the NASA project to determine whether or not, in our opinion, the development would make a worthwhile subject for licensing. If acceptable, we would consider attempting to license the development if NASA would approve the assignment of all rights to BDC; allow us to exclusively license in the U.S. for at least a period of time; and assign all foreign patent rights to us with no restrictions as to licensing.

It is understood we would provide the government of the United States with a royalty-free license for the U.S.

Should the development meet our criteria, we believe that licensing throughout the world would be the most efficient way to commercialize the technology.

Dr. Dale Rivers

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February 25, 1976

If our suggestions sound reasonable to you, we hope that you might discuss the situation with your NASA sponsors, and inform us of their reaction. If NASA would like clarification, we would be happy to talk directly with them.

Sincerely,

R. F. Dickerson

R. F. Dickerson
Vice President and
General Manager

RFD:jkg

cc: Dr. J. B. Jones
Head, Department of Mechanical Engineering
Virginia Polytechnic Institute
and State University
Blacksburg, VA 24061

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March 24, 1976

Mr. Dale B. Rivers
Assistant Professor
Virginia Polytechnic Inst. & State Univ.
Blacksburg, Virginia 24061

Dear Sir:

As you remember from our tel-con I believe that stereo fluoroscopy results could be very beneficial to industry.

Three dimensional information would enable industry to establish quantitative acceptance criteria. A significantly higher degree of reliability would certainly results.

Very truly yours,

UNITED STATES TESTING CO., INC.

W. C. Plumstead
Vice President

WCP/par